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EFFECT OF GRAZING UPON WESTERN YELLOW PINE REPRODUCTION IN CENTRAL IDAHO.

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TIMBER AND LIVE STOCK.

The western yellow pine forest is the most important source of timber in the area drained by the Columbia River and its tributaries east of the Cascades and north of the Snake River Valley. There are estimated to be approximately 7 million acres of western yellow pine (*Pinus ponderosa*) in the National Forests of this region, and there is probably an equal area outside the Forests. A conservative estimate of the National Forest stand is 50 billion board feet. At a growth rate of 100 board feet per acre per year [1] the western yellow pine land within the National Forests alone is capable of producing a sustained yield of 700 million board feet of lumber every year. A considerable portion of the timberland now in private ownership will probably be devoted eventually to other use, but much of it is more valuable for the continued production of timber than for any other purpose, so that it is reasonable to expect a total annual increment of at least a billion board feet on National Forest and privately owned land now occupied by western yellow pine. In this region growth is rapid, the quality of lumber produced is excellent, abundant natural reproduction follows logging, and the greater part of the area is accessible and fairly easy to log. The perpetuation of the western yellow pine stand therefore insures the continuation of an important part of the lumber industry in the Northwest.

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[1] See U. S. Department of Agriculture Bulletin 418, "Western Yellow Pine in Oregon," by T. T. Munger.

Because of the small rainfall over most of the untimbered part of the region and the consequent dependence of the rapidly developing agricultural industry upon irrigation, the maintenance of a forest cover in the mountains is as desirable for regulation of stream flow as for the production of timber.

The live-stock industry is important throughout this region, and the greater part of the forest area is utilized as spring or summer range for sheep and cattle. Although the quality of forage in western yellow pine stands varies widely, there are no areas which do not contain at least a small amount of palatable feed. Allowing even the very liberal average of 7 acres per sheep or 35 acres per cow—a large part of it has at least double this capacity—the western yellow pine type in the region described will supply summer range for a million sheep or 200,000 cattle.

The utilization of this forage, particularly on areas suited to sheep rather than to cattle, has presented a somewhat difficult problem, owing to the serious damage done by sheep to forest reproduction under the methods of handling hitherto prevalent and to the resulting idea common among silviculturists that sheep grazing and forest production can not be carried on together. To determine just how much harm is done to forest reproduction by sheep and how far this damage can be reduced by more careful use of the range, an intensive study was made on the Payette National Forest in central Idaho during the years 1912 to 1914, inclusive. It is believed that the results of this study, which are presented in the following pages, are fairly applicable to the entire region described:

STUDIES MADE ON THREE GRAZING ALLOTMENTS.

The effect of sheep grazing upon conifer reproduction was studied on a number of small sample plots well distributed over three separate grazing allotments. The study was carried on for three years on two allotments, one on Deadwood River and the other on Silver Creek, a tributary of the Middle Fork of the Payette River. In the third year, 1914, a third allotment, on the South Fork of the Payette, was also studied.

These areas, which are near the western edge of the deeply dissected central Idaho plateau, are characterized by a very broken surface, steep slopes, and numerous streams with deeply cut canyons. The soft granite, which underlies most of this part of the Forest, interspersed with numerous veins of quartzite, outcrops frequently on the steeper slopes and along the ridges, and the soil which is derived from it is very porous and dries out quickly. Narrow flats along the streams and occasional broader basins—probably once the beds of small lakes—are covered with alluvial soil of considerable depth.

Annual precipitation in the areas occupied by western yellow pine averages between 20 and 25 inches, of which a large part falls as snow. Snow usually goes off between mid-April at the lower altitudes and early June at the upper limits of yellow pine, and growth starts immediately thereafter. Considerable rain falls in June; but after the first week of July there is generally very little rain, except occasional thunder showers, until the first part of September. In early September a fall rainy period, with snow at the higher altitudes, is usual. During the summer, days are usually hot and nights cool. Altitudes above 5,000 feet are apt to be visited by killing frosts at any time, while the lower altitudes are, as a rule, free from frost from June 10 to September 1.

The grazing season for sheep commences some time in May in the lower western yellow pine country and about the middle or end of June in the higher and more remote areas, such as the Deadwood allotment, and lasts until the feed dries and becomes comparatively unpalatable, about the middle of August. The sheep are then held on the higher ranges until driven down by snow or cold weather, after which they sometimes spend a short time on the western yellow pine range on their way out to the open country.

Western yellow pine and Douglas fir seeds germinate for the most part during May and the first half of June at the lower, and during June and early July at the higher elevations, and occasional seedlings appear all through the summer. Lodgepole pine germination continues in considerable quantity during most of the season. Western yellow pine seedlings to a very large extent, and lodgepole pine to a less extent, occur in small compact bunches, the result of the seeds being buried by chipmunks.

THE DEADWOOD ALLOTMENT.

On the Deadwood allotment, which represents the upper extension of the range of the western yellow pine type, and all of which is above 5,000 feet altitude, the timber is largely a mixture of varying proportions of western yellow pine (*Pinus ponderosa*), Douglas fir (*Pseudotsuga taxifolia*), and lodgepole pine (*Pinus contorta*), with some alpine fir (*Abies lasiocarpa*), Engelmann spruce (*Picea engelmanni*), whitebark pine (*Pinus albicaulis*), and a very few specimens of western larch (*Larix occidentalis*). Most of the western yellow pine stands are on ridges or southern exposures between 5,000 and 6,000 feet elevation; where western yellow pine occurs on other sites it is usually scattered as individuals or groups in stands of other species. Practically none is found above 6,500 feet. By volume, approximately 40 per cent of the timber on this area is western yellow pine, 30 per cent Douglas fir, 25 per cent lodgepole pine, and 5 per cent other species.

The virgin stand is more or less broken by old burns and insect-killed areas, on most of which reproduction, especially of Douglas fir and lodgepole pine, has become well established. Other openings which have been occupied by dense brush contain only scattered tree reproduction. Advance reproduction of all species is common over most of the timbered area, though it is very unevenly distributed and of slow growth. Except on rather limited areas, western yellow pine reproduction is unsatisfactory in amount. At the time the study was started (1912) there were very few seedlings of this species under 10 years old, which indicates that years of abundant reproduction are very infrequent at this altitude. There were practically no saplings over 30 years old, probably on account of extensive fires in the early 80's. On the sample plots (see p. 5), which were located for the most part only where some western yellow pine reproduction was present, only 38 per cent of the seedlings were western yellow pine, while 32 per cent were Douglas fir and 30 per cent lodgepole pine.

The undergrowth on the western yellow pine part of the allotment, a varying mixture of grasses, weeds, and browse, is unevenly distributed and averages rather low in forage value.[1]

THE SILVER CREEK ALLOTMENT.

The Silver Creek area, from 4,600 to 5,500 feet in elevation, is fairly representative of the middle range of the western yellow pine type. The timber is of much better quality than that on the Deadwood allotment, and a much larger proportion is western yellow pine. Except on the moist flats along the creek, there is no lodgepole pine in the stand. By volume, approximately 75 per cent is western yellow pine, 20 per cent Douglas fir, and 5 per cent lowland white fir (*Abies grandis*).

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[1] Pine grass (*Calamagrostis rubescens*), arnica (*A. cordifolia*), geranium (*G. incisum*), lupine (*Lupinus spp.*), huckleberry (*Vaccinium membranaceum* and *V. scoparium*), spiraea (*S. lucida*), currant (*Ribes cereum*), willow (*Salix spp.*), and ceanothus (*C. velutinus*) are among the most widely distributed and characteristic plants. Other very common species include elk grass (*Carex geyeri*), blue grass (*Poa spp.*) blue bunch grass (*Festuca idahoensis*), silver dock (*Balsamorrhiza sagittata*), fireweed (*Chamaenerion angustifolium*), yarrow (*Achillea lanulosa*), hawkweed (*Hieracium scouleri*), paeony (*Paeonia brownii*), valerian (*Valeriana sitchensis*), bluebell (*Mertensia sp.*), meadow rue (*Thalictrum occidentalis*), Indian paintbrush (*Castilleja spp.*), foxglove (*Pentstemon spp.*), Indian tobacco (*Eriogonum spp.*), choke cherry (*Padus demissa*), fire cherry (*Prunus emarginata*) rose, (*Rosa spp.*), mountain ash (*Sorbus sambucifolia*), snowberry (*Symphoricarpos rotundifolius*), buck brush (*Kunzia tridentata*), and service berry (*Amelanchier alnifolia*).

Reproduction is abundant and well distributed and on account of the longer growing season growth is more rapid here than on the Deadwood area. On the sample plots 58 per cent of the seedlings were western yellow pine, 34 per cent Douglas fir, and 8 per cent lowland white fir.

The undergrowth on this allotment is dense and fairly evenly distributed; browse predominates. Its forage value is much higher than that on the Deadwood area because of its greater density and the larger proportion of palatable species.[1]

THE SOUTH FORK ALLOTMENT.

The South Fork allotment represents the best western yellow pine land in this region. Except for the main ridges, which reach 6,000 feet, most of the area is between 3,800 and 5,000 feet in elevation. Western yellow pine trees here occasionally reach a height of 190 feet. Western yellow pine makes up from 70 to 100 per cent of the volume of the stand, which probably averages for the entire area 85 per cent pine and 15 per cent Douglas fir.

The forage cover is denser and more palatable than that on either of the other two areas. Even on the south slopes there are few of the bare spots such as are common on the Deadwood allotment, but there are more brush areas so dense that they can not be utilized. Browse is the predominant type of forage, except on south slopes, on which grasses and weeds predominate.[2]

METHOD OF STUDY.

Small sample plots were chosen in such a way that they were well distributed over the three grazing allotments and were so located as to cover the greatest possible variety of conditions of topography, stand, forage cover, and use of the range. They are believed, therefore, to represent fairly the western yellow pine type of forest in the region described.

Thirty-nine plots were studied for the last year only, 40 more for two seasons, and 72 more for three years, a total of 151 plots with an aggregate area of approximately 75,000 square feet.

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[1] Characteristic plants are: Ceanothus (*C. velutinus* and *C. sanguineus*), ninebark (*Opulaster malvaceus*), huckleberry (*Vaccinium membranaceum*), choke cherry (*Padus demissa*), willows (*Salix spp.*), spiraea (*S. lucida*), snowberry (*Symphoricarpos rotundifolius*), rose (*Rosa spp.*), pine grass (*Calamagrostis rubescens*), silver dock (*Balsamorrhiza sagittata*), fireweed (*Chamaenerion angustifolium*), geranium (*G. incisum*), brome grass (*Bromus marginatus*), and meadow rue (*Thalictrum occidentale*).

[2] Characteristic plants are wheat-grass (*Agropyron spicatum*), June grass (*Koeleria cristata*), blue bunchgrass (*Festuca idahoensis*), brome (*Bromus marginatus*), blue grass (*Melica sp.* and *Poa sp.*), ceanothus (*C. sanguineus* and *C. velutinus*), ninebark (*Opulaster malvaceus*), snowberry (*Symphoricarpos rotundiolius*), spiraea (*S. lucida*), rose (*Rosa spp.*), willows (*Salix spp.*), service berry (*Amelanchier alnifolia*), mountain ash (*Sorbus sambucifolia*), maple (*Acer glabrum*), buck brush (*Kunzia tridentata*), syringa (*Philadelphus lewisii*), silver dock (*Balsamorrhiza sagittata*), asters (*Aster spp.*), geranium (*G. incisum*), sunflower (*Helianthella sp.*), pea-vine (*Lathyrus spp.*), lupine (*Lupinus spp.*), wild carrot (*Leptotaenia sp.*), fireweed (*Chamaenerion angustifolium*), hellebore (*Veratrum sp.*), brake (*Pteridium aquilinum pubescens*), nad meadow rue (*Thalictrum occidentale*).

The species and height of all seedlings on the plots were recorded at the beginning and end of each season, and in many instances at one or more other times during the summer. Injuries due to grazing or to other causes were noted at the same time. Record was also made of the approximate date when each plot was grazed, and of the intensity of grazing.

INJURIES TO REPRODUCTION CAUSED BY SHEEP GRAZING.

NATURE OF INJURIES.

Sheep injure forest reproduction directly both by browsing and by trampling. In the case of browsing the injury may be confined to a few needles or to the tips of side branches, the leader may be bitten off, or the bark may be gnawed. With conifers such injuries, except in extreme cases or when repeated, seldom result in permanent deformity or death. A careful study of comparative heights of uninjured seedlings and of those whose leaders had been removed several years before showed no perceptible difference in the rate of growth, except for the loss of the one year's increment. An uninjured side branch or a new bud takes the place of the leader, and the slight crook in the stem, which is evened out as its diameter increases, usually disappears within 10 years.

If the injury is repeated every year or two, of course the seedling will be permanently stunted and will never become a tree. This has happened along driveways which have been used for many years, and also on bed grounds which have been used several nights at a time year after year. It seldom happens except in such places. If an average of 1 per cent of the seedlings on an area are injured by grazing in one year, only 1 per cent of this 1 per cent will be likely to suffer a second injury the next year. In 20 years only 1.7 per cent of the seedlings will be likely to have been injured twice, and only 0.1 per cent three times.

Very severe browsing, such as frequently occurs on bed grounds which have been used too much, often kills the seedlings outright. In order to test the recovery from such injury, a number of seedlings between 6 inches and 3½ feet high were entirely defoliated in 1913. One year later 20 out of the 42 were dead, and the others, although they had put out new needles, appeared to be unhealthy and likely to die later. To test the effect of light browsing, only the foliage put out during the current year was removed from a number of other seedlings. This had no apparent lasting effect, since all were fully recovered within a year.

By trampling, sheep may bruise the seedling, bury it under loose soil or litter, uproot it, or break it. Such injuries, especially in case of the smaller seedlings, often cause death.

AMOUNT OF DAMAGE.

Table 1 shows the kind and amount of damage done by sheep on the different allotments during the course of the study.

The damage to seedlings more than a year old was negligible in quantity; a yearly average of 1.9 per cent of the number on grazed plots was killed on the Deadwood area, and 3.7 per cent on the Silver Creek area. The one year's record for the South Fork (4.7) indicates, when compared with the same year's record on the other allotments, that the yearly average for a three-year period would probably have been between the Deadwood and Silver Creek averages. Of seedlings less than one year old, on Deadwood an average of 15.4 per cent were killed, and on Silver Creek 24.9 per cent. The greater mortality of both classes of seedlings on the Silver Creek area was due partly to the greater intensity of grazing on that allotment and partly to differences in the relative distribution of ages; the Silver Creek area had a much larger proportion of reproduction less than 10 years old. These figures show the proportion of damage on grazed plots alone; that is, they indicate the maximum loss which would result if the sheep grazed over every square yard of their allotment. As a matter of fact an area is seldom grazed so closely unless it is very much overstocked; a great many spots are missed, and many of them are likely to be patches of reproduction, since there is usually little palatable forage in such places.

The last columns in Table 1 show the proportion of injury to the total number of seedlings on all of the plots on each allotment. On the Deadwood area, which was grazed rather lightly, averages of 1.1 per cent of the older seedlings and 8.8 per cent of those less than a year old were killed each year, while on the closely grazed Silver Creek area 2.5 per cent and 14.8 per cent, respectively, were killed.

Of the older seedlings on grazed plots on Deadwood but 0.7 per cent were browsed, and of those on Silver Creek 1.5 per cent. Considering all plots whether grazed or not, 0.4 per cent of the seedlings on Deadwood and 1.1 per cent of those on Silver Creek were browsed each year; and fully one-third of these "injuries" consisted of slight browsing of needles or tips of lateral branches only. The smaller proportion of one-year seedlings classed as "injured" is due to the fact that they are usually killed if injured at all.

Of the three important species present, western yellow pine appears to be most liable to browsing injury, lodgepole pine somewhat less so, and Douglas fir least. White fir is practically never browsed.

TABLE 1.—*Seedlings killed and injured by sheep.*

(A) SEEDLINGS MORE THAN ONE YEAR OLD.

Year and allotment.	Total number of seedlings on grazed plots.					Browsed.																
						Needles.		Side branches.			Leaders.			Bark.		Total.			Per cent of number on grazed plots.			
	Western yellow pine.	Douglas fir.	Lodgepole pine.	White fir.	All.	Western yellow pine.	Lodgepole pine.	Western yellow pine.	Douglas fir.	Lodgepole pine.	Western yellow pine.	Douglas fir.	Lodgepole pine.	Western yellow pine.	Douglas fir.	Western yellow pine.	Douglas fir.	Lodgepole pine.	Western yellow pine.	Douglas fir.	Lodgepole pine.	All.
1912.																						
Deadwood	1,542	1,372	985	.....	3,899	9	1	.....	1	.....	6	.....	.....	1	.....	16	1	1	1.0	0.1	0.1	0.5
Silver Creek	976	746	.....	199	1,921	2	.....	.....	.....	.....	1	.....	.....	.....	.....	3	.....	.....	.3	.....	.....	.2
	2,518	2,118	985	199	5,820	11	1	.....	1	.....	7	.....	.....	1	.....	19	1	1	.8	.0	.1	.4
1913.																						
Deadwood	1,700	1,558	1,034	.....	4,292	3	1	.....	.....	.....	6	8	1	5	.....	14	7	2	.8	.5	.2	.6
Silver Creek	1,366	753	.....	115	2,243	13	.....	2	4	.....	35	8	.....	1	.....	51	12	.....	3.8	1.6	.....	2.8
	3,066	2,311	1,034	115	6,526	16	1	2	4	.....	41	16	1	6	.....	65	19	2	2.1	.8	.2	1.3
1914.																						
Deadwood	1,600	1,421	1,205	.....	4,226	16	1	.....	.....	3	17	4	5	.....	1	33	5	9	2.1	.4	.7	1.1
Silver Creek	775	667	.....	102	1,544	3	.....	1	.....	.....	16	1	.....	.....	.....	20	1	.....	2.6	.1	.....	1.4
South Fork	1,104	42	.....	.....	1,146	2	.....	9	.....	.....	12	.....	.....	1	.....	24	.....	.....	2.2	.....	.....	2.1
	3,479	2,130	1,205	102	6,916	21	1	10	.....	3	45	5	5	1	1	77	6	9	2.2	.3	.7	1.3

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BROWSE RANGE UNDER YELLOW PINE TIMBER.

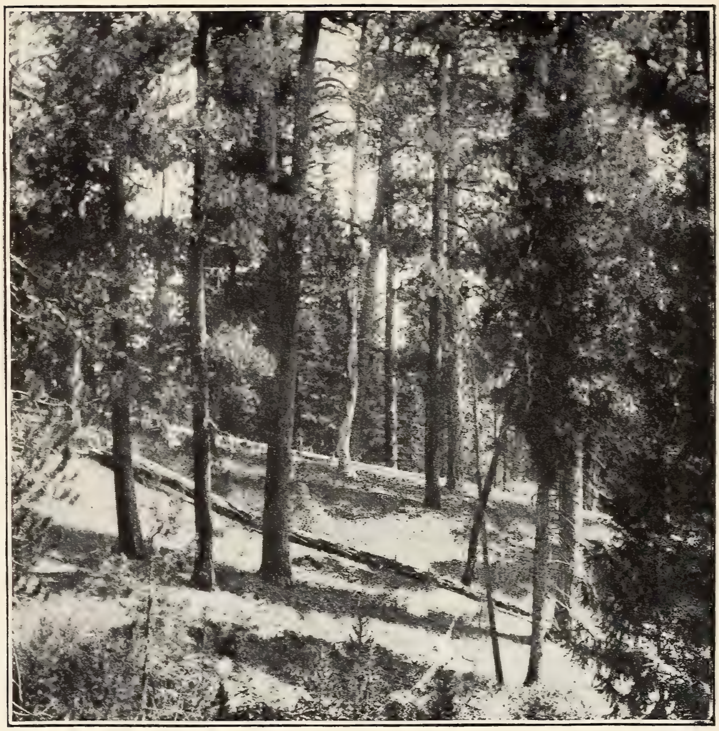

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FIG. 1.—PINE-GRASS RANGE TYPICAL OF MUCH OF THE YELLOW PINE TIMBER RANGE.

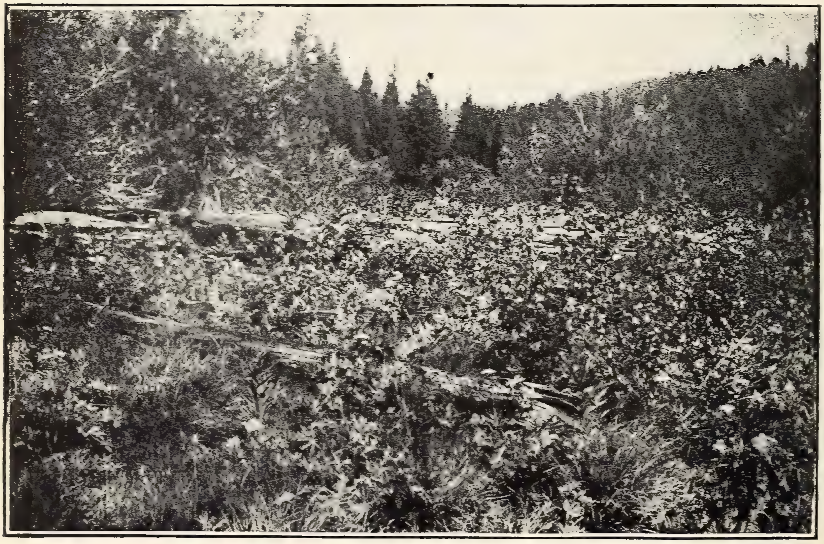

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FIG. 2.—BROWSE, WEED, AND GRASS RANGE TYPICAL OF OPENINGS IN YELLOW PINE AND DOUGLAS FIR STANDS.

(B) SEEDLINGS LESS THAN ONE YEAR OLD.

1912.																						
Deadwood	29	117	143	....	289	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Silver Creek	1,226	51	....	22	1,299	3	....	....	....	....	9	....	....	....	....	....	....	....	1.0	....	....	1.0
	1,255	168	143	22	1,588	3	....	....	....	....	9	....	....	....	....	....	....	....	1.0	....	....	1.0
1913.																						
Deadwood	1,392	334	990	....	2,716	....	....	....	....	....	7	....	1	....	....	....	....	....	.5	....	.1	.3
Silver Creek	1,797	327	....	14	2,138	....	....	....	....	....	7	....	....	....	....	....	....	....	.4	....	....	.3
	3,189	661	990	14	4,854	....	....	....	....	....	14	....	1	....	....	....	....	....	.4	....	.1	.3
1914.																						
Deadwood	22	12	51	....	85	....	....	....	....	....	....	1	....	....	....	....	....	....	....	8.3	....	1.2
Silver Creek	6	3	....	....	9	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
South Fork	5	....	....	....	5	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	33	15	51	....	99	....	....	....	....	....	....	1	....	....	....	....	....	....	....	6.7	....	1.0

TABLE 1.—*Seedlings killed and injured by sheep*—Continued.

(A) SEEDLINGS MORE THAN ONE YEAR OLD—Continued.

Year and allotment.	Trampled.							Killed.										Total number of seedlings on all plots.					Per cent of number on all plots.								
	Number.			Per cent of number on grazed plots.				Number.				Per cent of number on grazed plots.										Injured.				Killed.				
	Western yellow pine.	Douglas fir.	Lodgepole pine.	Western yellow pine.	Douglas fir.	Lodgepole pine.	All.	Western yellow pine.	Douglas fir.	Lodgepole pine.	White fir.	Western yellow pine.	Douglas fir.	Lodgepole pine.	White fir.	All.	Western yellow pine.	Douglas fir.	Lodgepole pine.	White fir.	All.	Western yellow pine.	Douglas fir.	Lodgepole pine.	All.	Western yellow pine.	Douglas fir.	Lodgepole pine.	White fir.	All.
1912.																														
Deadwood	36	9	13	2.3	0.7	1.3	1.5	7	17	14	....	0.5	1.2	1.4	....	1.0	1,877	1,689	1,074	.....	4,640	2.8	0.6	1.3	1.7	0.4	1.1	1.3	....	0.9
Silver Creek	3	3	....	.3	.4	....	.3	16	9	....	....	1.6	1.2	....	....	1.3	976	748	....	199	1,923	.6	.4	....	.5	1.6	1.2	....	....	1.3
	39	12	13	1.5	.6	1.3	1.1	23	26	14	....	.9	1.2	1.4	....	1.1	2,853	2,437	1,074	199	6,563	2.0	.6	1.3	1.3	.8	1.1	1.3	....	1.0
1913.																														
Deadwood	1	7	....	.1	.5	....	.2	7	16	24	....	.4	1.0	2.3	....	1.1	2,412	2,726	1,576	.....	6,714	.7	.6	.1	.5	.3	.6	1.6	....	.7
Silver Creek	2	....	....	.1	....	....	.1	31	18	....	8	2.3	2.4	....	7.0	2.6	1,545	888	....	229	2,662	3.6	1.4	....	2.6	2.1	2.1	....	3.5	2.2
	3	7	....	.1	.3	....	.1	38	34	24	8	1.2	1.5	2.3	7.0	1.6	3,957	3,614	1,576	229	9,376	1.8	.8	.1	1.1	1.0	1.0	1.6	3.5	1.1
1914.																														
Deadwood	4	4	4	.2	.3	.3	.3	29	33	92	....	1.8	2.3	7.6	....	3.7	3,387	2,916	2,582	.....	8,885	1.1	.3	.5	.7	.8	1.2	3.6	....	1.7
Silver Creek	1	....	....	.1	....	....	.1	87	25	....	1	11.2	3.6	....	1.0	7.3	1,666	999	....	233	2,898	1.3	.1	....	.7	5.2	2.5	....	.5	3.9
South Fork	4	....	....	.4	....	....	.4	47	7	....	....	4.2	16.7	....	....	4.7	2,383	973	....	.....	3,356	1.2	....	....	.8	2.0	.7	....	....	1.6
	9	4	4	.3	.2	.3	.2	163	65	92	1	4.7	3.1	7.6	1.0	4.6	7,436	4,888	2,582	233	15,139	1.1	.2	.5	.7	2.2	1.4	3.6	.5	2.1

(B) SEEDLINGS LESS THAN ONE YEAR OLD—Continued.

1912.																														
Deadwood	....	....	....	....	....	....	....	6	23	8	....	20.7	19.6	5.6	....	12.8	47	176	208	.....	431	....	....	....	....	12.8	13.1	3.8	....	8.6
Silver Creek	1	....	....	.1	....	....	.1	166	8	....	2	13.6	15.7	....	9.1	13.5	1,301	59	....	22	1,382	1.0	....	....	.9	12.8	13.6	....	9.1	12.7
	1	....	....	.1	....	....	.1	172	31	8	2	13.7	18.5	5.6	9.1	13.4	1,348	235	208	22	1,813	1.0	....	....	.7	12.8	13.2	3.8	9.1	11.7
1913.																														
Deadwood	4	1	1	.3	.3	.1	.2	295	58	110	....	21.2	17.4	11.1	....	16.9	2,059	463	1,905	.....	4,427	.5	.2	.1	.2	14.3	12.5	5.8	....	10.5
Silver Creek	1	1	....	.1	.3	....	.1	530	60	....	6	29.5	18.4	....	42.8	27.9	2,076	597	....	25	2,698	.4	.2	....	.3	25.5	10.0	....	24.0	22.1
	5	2	1	.2	.3	.1	.2	825	118	110	6	25.9	17.9	11.1	42.8	21.8	4,135	1,060	1,905	25	7,125	.5	.2	.1	.3	20.0	11.1	5.8	24.0	14.9
1914.																														
Deadwood	....	....	....	....	....	....	....	6	....	8	....	27.3	.....	15.7	....	16.5	32	22	139	.....	183	....	4.6	....	.5	18.7	....	5.7	....	7.2
Silver Creek	....	....	....	....	....	....	....	2	1	....	....	33.3	33.3	....	....	33.3	19	12	....	0	31	....	....	....	....	10.5	8.3	....	....	9.7
South Fork	....	....	....	....	....	....	....	5	....	....	....	100.0	.....	....	....	100.0	42	13	....	.....	55	....	....	....	....	11.9	....	....	....	9.1
	....	....	....	....	....	....	....	13	1	8	....	39.4	6.7	15.7	....	22.2	93	47	139	0	269	....	2.1	....	.4	14.0	2.1	5.7	....	7.9

SIZES INJURED.

Table 2 shows the total amount of injury done by sheep on all the sample plots during the period of the study, classified according to the size of seedlings injured. Of the 1,782 seedlings killed, 1,294, or 73 per cent, were less than a year old, while only 11, or about one-half of 1 per cent, were over 6 inches in height. Only one seedling over 18 inches high was killed by sheep during the three years. Only one sapling over 3.5 feet high was browsed or trampled; most of the injuries from browsing or trampling were confined to seedlings less than 1.5 feet in height.

The relative mortality of seedlings of different sizes is shown in Table 3. During the first few years seedlings succumb very easily to slight injuries, because of their small size, shallow root system, and the lack of woody matter in their stems. The loss due to grazing decreased from about 20 per cent for seedlings in their first year to 11 per cent for those in their second and third years. By the end of the third year they are from 2 to 4 inches high (depending on species and site), their stems have become woody and fairly tough, and their roots penetrate the soil for a foot or more, so that they are not easily uprooted by trampling nor exposed to drying by the loosening of the soil. Injury from grazing is so slight after this that there is no need for closing reproduction areas to sheep after the third year, though it may be desirable to graze such areas lightly for a few years more, until the seedlings reach a height of 6 inches.

TABLE 2.—*Relation between size of seedlings and injury by grazing.*

(Total injuries for three years on sample plots on all allotments.)

Species and height class.	Injured.						
	Needles.	Side branches.	Leader.	Bark.	Trampled.	All.	Killed.
Western yellow pine:							
Under 1 year	3	....	23	....	6	32	1,010
1 year old to 6 inches high	10	....	46	....	13	69	216
6 inches to 1½ feet	31	1	38	5	36	111	7
1½ to 2½ feet	7	10	8	1	2	28	1
2½ to 3½ feet	....	1	1	2	....	4	....
Douglas fir:							
Under 1 year	....	....	1	....	2	3	150
1 year old to 6 inches high	....	....	8	....	10	18	124
6 inches to 1½ feet	....	1	9	....	12	22	1
1½ feet to 2½ feet	....	2	2	....	1	5	....
2½ to 3½ feet	....	2	1	1	....	4	....
Lodgepole pine:							
Under 1 year	....	....	1	....	1	2	126
1 year old to 6 inches high	1	....	1	....	6	8	128
6 inches to 1½ feet	1	1	5	....	6	13	2
1½ to 2½ feet	1	....	....	....	3	4	....
2½ to 3½ feet	....	1	....	....	2	3	....
3½ to 4½ feet	....	1	....	....	....	1	....
White fir:							
Under 1 year	....	....	....	....	....	....	8
1 year old to 6 inches high	....	....	....	....	....	....	9

TABLE 3.—*Seedlings killed by sheep, by sizes.*

(Percentages of total numbers on grazed plots.)

Year and size class.	Western yellow pine.	Douglas fir.	Lodgepole pine.	All.
1912:				
Less than 1 year[1]	13.7	18.5	5.6	13.4
1 year old to 6 inches high	3.1	2.7	3.1	3.0
6 inches to 1½ feet	....	....	....	....
1913:				
Less than 1 year	25.9	17.9	11.1	21.8
1 to 2 years	4.4	7.1	7.2	5.5
2 years old to 6 inches high	.8	2.2	1.6	1.6
6 inches to 1½ feet	.4	....	.9	.3
1914:				
Less than 1 year	39.4	6.7	15.7	22.2
1 to 2 years	15.5	20.3	10.9	14.4
2 to 3 years	9.1	9.9	23.6	11.4
3 years old to 6 inches high	.4	1.6	1.4	1.1
6 inches to 1½ feet	.3	.2	....	.2
Average:				
Less than 1 year	22.4	17.8	10.8	19.8
1 to 2 years	10.8	13.9	9.9	11.0
2 to 3 years	9.1	9.9	23.6	11.4
3 years old to 6 inches high	1.5	2.1	2.2	1.9
6 inches to 1½ feet	.2	....	.6	.2

[1] Number killed by sheep in 1912 partly estimated.

Tables 4 and 5 show the rate of growth in height of the important species on the Deadwood allotment, which corresponds to sites of poorer quality than the average, and on the South Fork allotment, which corresponds to average or better western yellow pine sites. The figures given represent growth of advance reproduction, mostly under timber rather than in openings. For comparison, the growth of dominant western yellow pine seedlings in eastern Oregon[1] is also shown.

TABLE 4.—*Juvenile height growth on experimental area.*

Age in years.	Western yellow pine.			Douglas fir.		Lodgepole pine.
	Deadwood.	South Fork.	Blue Mountains.	Deadwood.	South Fork.	Deadwood.
	Height in feet.					
5	0.3	0.5	0.8	0.2	0.2	0.2
10	.6	.9	1.7	.4	.6	.6
15	1.2	2.1	2.7	.8	1.3	1.3
20	2.0	3.5	....	2.4	2.2	2.4
25	3.0	5.5	....	2.1	3.6	4.0
30	4.2	9.6	....	2.8	5.5	6.2
35	5.7	13.9	....	3.7	9.5	10.0
40	8.2	....	....	4.7	....	15.7
Number seedlings basis	586	738	1,182	914	521	206

TABLE 5.—*Years required to reach a given height.*

Height in feet.	Deadwood.			South Fork.	
	Western yellow pine.	Douglas fir.	Lodgepole pine.	Western yellow pine.	Douglas fir.
	Years.	*Years.*	*Years.*	*Years.*	*Years.*
0.5	8	12	9	5	10
1.5	17	20	16	13	16
2.5	23	28	20	17	20
3.5	27	34	24	20	25
4.5	31	39	27	23	28
5.5	35	43	29	25	30

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[1] From United States Department of Agriculture Bulletin 418, Western Yellow Pine in Oregon, by T. T. Munger.

After seedlings are 6 inches high the damage caused by moderately close grazing is negligible. According to Table 5, western yellow pine reaches this height in 5 years on the better sites or in 8 years on the poorer sites, Douglas fir in from 10 to 12 years, and lodgepole pine in 9 years. There is practically no damage at all after seedlings reach 1.5 feet in height, or after from 13 to 17 years for western yellow pine, from 16 to 20 years for Douglas fir, and 16 years for lodgepole pine.

From Table 3 and the height growth it is computed that on the Deadwood allotment 46.5 per cent of the western yellow pine which germinates will be killed if the area is grazed every year, or 8.7 per cent if grazing is eliminated until seedlings have passed their third year. On the South Fork the figures will be 43.4 per cent and 5.7 per cent. Of Douglas fir in Deadwood, 48.8 per cent will be killed by grazing every year, or 14.3 per cent if it is suspended for three years; on the South Fork 44.2 per cent, or 9.9 per cent after three years, will be lost. In Deadwood 39.7 per cent of the lodgepole pine seedlings will be killed, or 15.1 per cent if the area is grazed after the third year only.

According to Table 3 a much larger proportion of western yellow pine seedlings less than a year old are killed than of Douglas fir, while only half as many of lodgepole pine are killed. This is probably due partly to the taller and more succulent and brittle stems of western yellow pine seedlings and partly to the fact that lodgepole pine reproduction is more abundant where there is comparatively little palatable forage cover, so that grazing is apt to be lighter on spots where lodgepole pine seedlings predominate than where western yellow pine is the prevailing species. The characteristic distribution of western yellow pine seedlings in clumps planted by chipmunks and mice (Douglas fir and lodgepole pine usually occurring singly) may also result in a somewhat larger mortality, since the disturbance which affects one seedling in a clump affects the whole group.

Table 8 indicates that as a general thing western yellow pine is less likely to be killed after its third year than is Douglas fir or lodgepole pine. This may be due to the larger size of three-year old yellow pine seedlings.

SEASON OF INJURY.

To determine the relation between the amount of damage and the time of year when the grazing was done, the plots grazed on the Deadwood allotment in 1913 were grouped into three classes: (*a*) those grazed early in the season, or up to the latter part of July, which in 1913 was a fairly moist period; (*b*) those grazed in midseason, from late in July to the middle of August; and (*c*) those grazed late, or after the middle of August, the driest part of the season. Table 6 shows the relative amount of damage done during each period.

TABLE 6.—*Grazing injuries, by time of year, in percentages of number of seedlings on the plots at the time they were grazed.*

(Deadwood allotment, 1913.)

Time of grazing and species.	Injured (over 1 year old).		Killed.	
	Browsed.	Trampled.	Under 1 year old.	Over 1 year old and under 1½ feet high.
Early summer:				
Western yellow pine	(1)	...	24.2	0.5
Douglas fir	(1)	...	20.6	.8
Lodgepole pine	(1)	...	18.5	4.8
All	.1	...	23.4	1.4
Middle summer:				
Western yellow pine	(1)	...	14.3	.5
Douglas fir	(1)	(1)	24.7	1.4
Lodgepole pine	(1)	(1)	6.8	1.5
All	.6	.2	11.6	1.1
Late summer:				
Western yellow pine	(1)	...	6.7	...
Douglas fir	(1)	(1)	8.9	...
Lodgepole pine	(1)	(1)	9.3	2.0
All	.5	.1	8.0	.5

[1] Very small.

Injuries which did not result in death, particularly those due to browsing, though insignificant at any season, were greater late in the season than during the earlier period. This is probably due to the drying of the succulent forage of the early part of the season and to the greater liking of sheep for browse types of forage as the season advances.

The proportion of seedlings killed by grazing, particularly of those less than a year old, was very much greater early in the season than it was later. The reasons for this are that early in summer the seedlings are rather brittle, with little wood in their stems; their roots do not go down very deep; the soil is moist and easily shoved out of place by the sheep; and seedlings injured early are either killed outright or have small chance to recover because of the dry period which follows the injury. By the middle of August the season's growth is nearly completed, the stems are tougher, the roots deeper and more widely spread, the soil is more firmly packed, and an injury is soon followed by the fall rainy period and the long winter period of rest, so that there is a fair chance for recovery from slight disturbance.

RELATION BETWEEN AMOUNT OF DAMAGE AND INTENSITY OF GRAZING.

The relation between intensity of grazing and amount of damage is shown in Table 7. Where the surface of the ground was not appreciably disturbed by trampling and very little of the forage cover was eaten the plot was classed as "lightly grazed"; where most of the palatable forage was eaten, but the ground was not seriously trampled, the plot was classed as "moderately grazed"; and where practically all forage was eaten and the surface considerably worn by trampling, it was called "closely grazed." Bed grounds, where the sheep bunched up for the night or during the middle of the day and where grazing was most intense, were grouped separately.

TABLE 7.—*Grazing injuries according to intensity of grazing.*

(All years and allotments.)

(A) SEEDLINGS MORE THAN ONE YEAR OLD (1912 TO 1914).

Intensity of grazing.	Seedlings on plots.				Numbers.									
					Killed.				Browsed.			Trampled.		
	Western yellow pine.	Douglas fir.	Lodgepole pine.	White fir.	Western yellow pine.	Douglas fir.	Lodgepole pine.	White fir.	Western yellow pine.	Douglas fir.	Lodgepole pine.	Western yellow pine.	Douglas fir.	Lodgepole pine.
Light	2,503	2,446	1,392	168	35	37	25	1	13	4	.....	6	5	1
Moderate	2,174	1,761	714	193	59	33	52	8	25	3	.....	9	1	2
Close	2,388	1,351	398	76	80	23	11	.....	40	6	2	18	4	5
Beds	1,188	993	685	.....	50	32	42	.....	83	13	10	18	13	9

(B) SEEDLINGS LESS THAN ONE YEAR OLD (1913 AND 1914).

Light	252	85	496	1	16	12	26	.....	1	.....	.....	.....	.....	.....
Moderate	947	138	385	11	230	29	58	6	.....	.....	.....	.....	.....	.....
Close	1,200	240	106	2	344	35	18	.....	12	.....	.....	1	.....	.....
Beds	823	213	54	.....	244	45	16	.....	2	.....	1	3	.....	1

(A) SEEDLINGS MORE THAN ONE YEAR OLD (1912 TO 1914)—Continued.

Intensity of grazing.	Per cent.												
	Killed.					Browsed.				Trampled.			
	Western yellow pine.	Douglas fir.	Lodgepole pine.	White fir.	All.	Western yellow pine.	Douglas fir.	Lodgepole pine.	All.	Western yellow pine.	Douglas fir.	Lodgepole pine.	All.
Light	1.4	1.5	1.8	0.6	1.5	0.5	0.2	......	0.3	0.2	0.2	0.1	0.2
Moderate	2.7	1.9	7.4	4.1	3.2	1.1	.1	......	.6	.4	.1	.3	.3
Close	3.3	1.7	2.8	......	2.7	1.7	.5	.5	1.1	.8	.3	1.3	.7
Beds	3.8	3.2	6.1	......	4.2	7	1.3	1.5	3.7	1.5	1.3	1.3	1.4

(B) SEEDLINGS LESS THAN ONE YEAR OLD (1913 AND 1914)—Continued.

Light	6.3	14.1	5.2	......	6.5	.4	......	......	.1	......	......	......	......
Moderate	24.3	21.0	15.1	54.5	21.8	......	......	......	......	......	......	......	......
Close	28.7	14.6	19	......	25.7	1	......	......	.8	......	......	......	.1
Beds	29.6	21.1	29.6	......	29	.2	......	1.9	.3	.4	......	1.9	.4

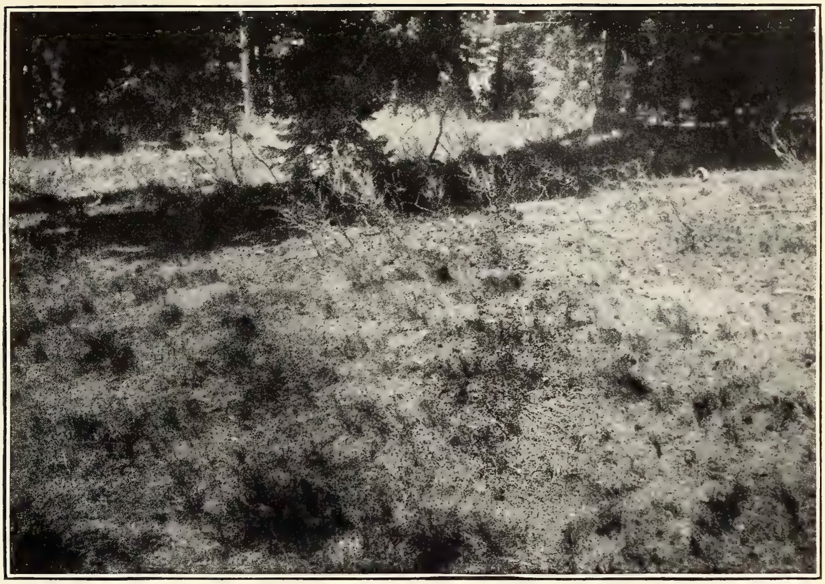

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FIG. 1.—AREA USED FOR BED GROUND FOR ONE NIGHT.

Injury to reproduction and to forage cover is not serious.

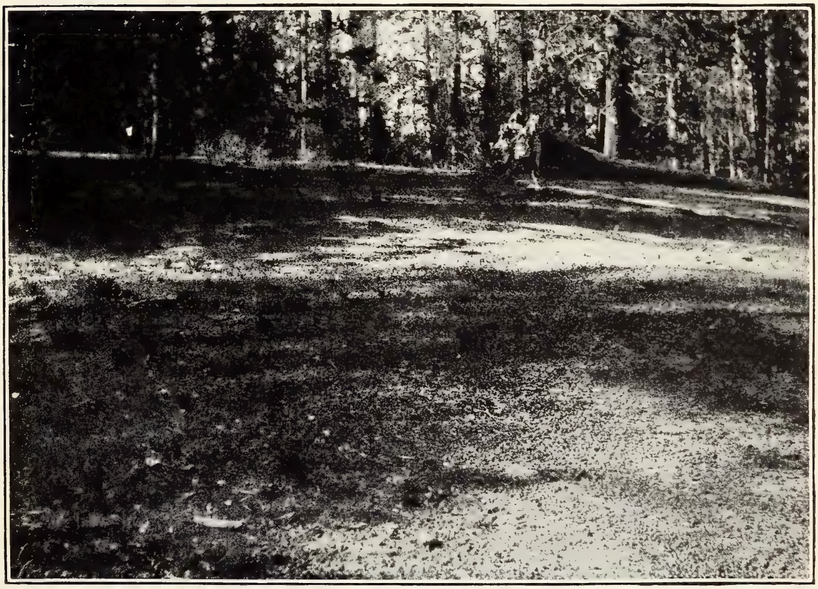

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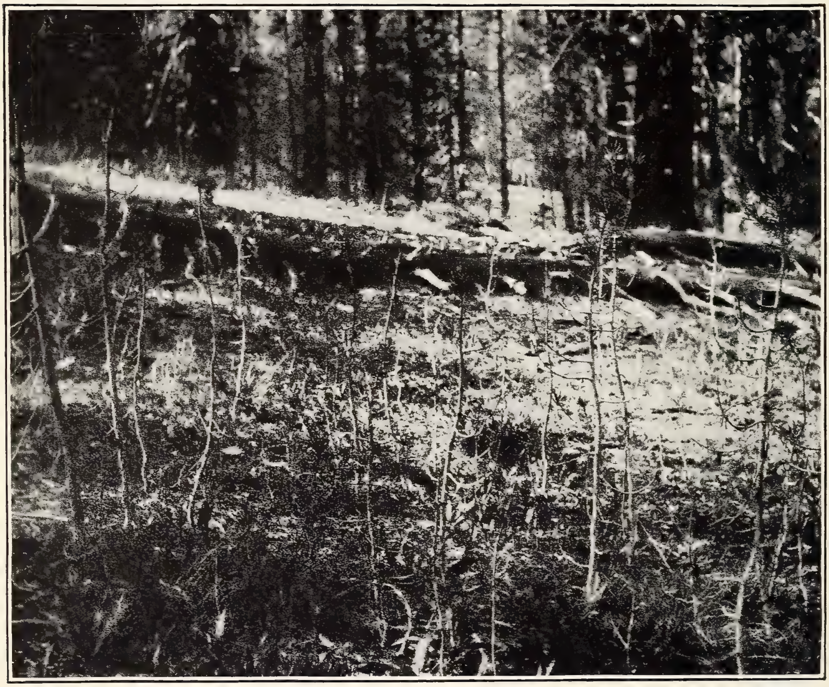
FIG. 2.—BED GROUND USED SEVERAL NIGHTS IN SUCCESSION.

Note entire absence of vegetation and thick layer of mulch.



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INJURY TO LODGEPOLE PINE REPRODUCTION ON BED GROUND USED FOR SEVERAL NIGHTS.

Few of these saplings recovered from the injury.

As would be expected, the amount of injury and death increased fairly constantly with increased intensity of grazing. Except on bed grounds and areas grazed with similar intensity, the damage was not very serious for seedlings more than a year old, and even in such places only 4 per cent of the seedlings were killed. A considerable proportion, from 20 to 30 per cent, of those less than a year old were killed on all except the lightly grazed plots, where only 6.5 per cent were lost.

Table 8 shows that after their third year a very small proportion of seedlings, less than 1 per cent per year, is killed by grazing of moderate intensity; that is, by grazing close enough to utilize practically all of the palatable forage.

TABLE 8.—*Seedlings from 3 years old to 1½ feet high killed by sheep on moderately grazed plots.*

Allotment and species.	Per cent of seedlings on grazed plots killed.			
	1912	1913	1914	Average for period.
Deadwood:				
Yellow pine			0.7	0.26
Douglas fir		.5	.8	.47
Lodgepole pine		.5	2.5	1.08
All		.3	1.1	.51
Silver Creek:				
Yellow pine	6.5			1.11
Douglas fir	4.6	1.6		1.07
White fir				
All	5.5	.8		.95
South Fork:				
Yellow pine			.8	
Douglas fir			33.3	
All			3	
All areas:				
Yellow pine				.52
Douglas fir				.98
Lodgepole pine				1.08
White fir				
All				.76

Although the plots did not happen to be located so as to show the effect of repeated use of the same bed ground, it was established by observation that the damage on the second and succeeding nights was very much greater in proportion than that on the first night. The first time a bed ground is used the sheep spend the time just before dark and in the morning before they are driven off the area in browsing, first, such forage plants as are present, and then, if they are left too long or forage is scanty, the conifer reproduction. Very few seedlings were browsed on the experimental areas on bed grounds used for one night only. On one plot which was part of a bed ground in 1913, only 37 out of 160 seedlings less than a year old were killed by the sheep. If sheep are driven back to the same bed the next night, or at any time before a full new crop of foliage has sprung up, the damage by browsing is almost always very serious, as there remain only the least palatable forage plants and the conifers. On bed grounds used for several times in succession every green leaf is removed, and even the bark of saplings up to several inches in diameter is gnawed off. For like reason similar conditions prevail along driveways used for several bands of sheep.

CUMULATIVE EFFECT OF GRAZING.

The cumulative effect of three years' grazing is indicated in Table 9, which shows in percentages of the numbers originally on the plots in the spring of 1912, the numbers gained by germination, those lost by death, and the net result. The figures, which are grouped according to the average intensity of grazing during the three years, show plainly that in spite of greater germination on the more closely grazed plots the net loss increased rapidly with increased intensity of grazing. While there was an increase in the number of seedlings on plots grazed lightly or not at all, there was a slight decrease on moderately grazed plots, and a considerable loss on closely grazed areas.

TABLE 9.—*Changes in numbers of seedlings from spring 1912 to fall, 1914, on 71 plots on Deadwood and Silver Creek, in percentages of the numbers originally on the plots in the spring of 1912.*

Average intensity of grazing.	Western yellow pine.			Douglas fir.			Lodgepole pine.		
	Per cent alive at end.	Per cent germinated.	Per cent died.	Per cent alive at end.	Per cent germinated.	Per cent died.	Per cent alive at end.	Per cent germinated.	Per cent died.
Not grazed	96.3	61.5	65.2	104.6	54.4	49.8	143.8	59.7	15.9
Grazed lightly	94.4	42.7	48.3	100.6	30.2	29.6	172.3	184.7	112.4
Grazed moderately	78.4	76.0	97.6	102.4	25.2	22.8	133.1	87.3	54.2
Grazed closely	73.2	101.7	128.5	96.1	61.2	65.1	99.4	38.2	38.8
Beds	65.3	133.7	168.4	100.0	316.7	316.7			
All	83.4	71.8	88.4	101.3	36.7	35.4	146.1	108.9	62.8

Average intensity of grazing.	White fir.			All species.		
	Per cent alive at end.	Per cent germinated.	Per cent died.	Per cent alive at end.	Per cent germinated.	Per cent died.
Not grazed	100.0	12.9	12.9	110.3	54.3	44.0
Grazed lightly	105.3	21.1	15.8	110.6	64.3	53.7
Grazed moderately	100.0	28.5	28.5	93.6	56.6	63.0
Grazed closely				81.2	86.5	105.3
Beds			100.0	67.9	150.9	183.0
All	100.5	20.7	20.2	98.5	64.9	66.4

RELATION BETWEEN AMOUNT OF DAMAGE AND AMOUNT AND CHARACTER OF THE FORAGE.

The quantity of palatable forage on a given area may affect the amount of damage done in two ways. If the total quantity of feed is too small for the number of stock allotted to the area, there will probably be considerable browsing injury and more injury from trampling than if there is abundant feed so that the sheep need not wander around looking for it. On the other hand, whether the allotment as a whole has ample forage for the allotted stock or not, the injury due to trampling, which causes most of the deaths of small seedlings, is likely to be greatest on those parts of the allotment where the amount of palatable forage is greatest. The reason for this is that the sheep will spend more time where forage is abundant than where it is scanty.

Trampling is more serious on steep slopes than on more level places, except around beds, watering places, or along driveways, because of the tendency of sheep on hillsides to follow each other's footsteps and thus wear trails, and because of the greater likelihood that seedlings will be uprooted or buried by trampling in such places.

Where the forage is composed largely of tender herbaceous vegetation reproduction is more subject to damage than where there are shrubs or dense tufts of perennial grasses or weeds to protect the seedlings.

COMPARISON OF THE DAMAGE CAUSED BY SHEEP AND BY OTHER AGENCIES.

To account for deaths due directly or indirectly to grazing, but whose cause could not be definitely traced, a comparison was made between the total deaths during the summer on grazed and ungrazed plots.

With very few exceptions, the mortality on grazed plots was the greater for all species and size classes. Excepting the 2 to 3 year old white fir, for which there were too few figures for a good average, this difference in favor of ungrazed plots was very marked for all seedlings less than 6 inches high.

Table 10 indicates that a large number of the smaller seedlings died even where no grazing was done. The total amount of injury and death during the period of the study due to causes other than grazing is summarized in Table 11. Tables 12 and 13 compare grazing injuries with those due to other causes for the different species and allotments.

The increase in the number of deaths in 1913 and 1914 was due to the greater number of plots and the larger number of seedlings examined, and to the greater proportion of seedlings less than 1 year old which resulted from the abundant germination, especially in 1913.

TABLE 10.—*Deaths during summer, from all causes, on grazed and ungrazed plots.*

(All years and allotments.)

Height class.	Western yellow pine.		Douglas fir.		Lodgepole pine.		White fir.		All.	
	Not grazed.	Grazed.	Not grazed.	Grazed.	Not grazed.	Grazed.	Not grazed.	Grazed.	Not grazed.	Grazed.
	Deaths in per cent of the numbers of seedlings on the plots.									
Under 1 year	36.5	59.2	35.2	50.0	24.2	34.7	27.3	36.1	31.3	53.4
1 to 2 years	19.0	25.2	23.6	29.9	17.1	21.1	43.7	44.8	19.8	24.9
2 to 3 years	12.5	17.8	11.8	17.8	7.9	25.2	40.0	25.0	11.8	19.0
3 years old to 6 inches high	4.9	6.1	2.1	3.9	2.8	5.6	......	1.0	2.9	4.8
6 inches to 1½ feet	1.1	.7	.3	.4	......	.5	......	......	.6	.6
1½ to 2½ feet	.3	.6	......	.1	......	......	......	......	.2	.3
2½ to 3½ feet	.4	.2	......	......	......	......	......	......	.2	.1
3½ to 4½ feet	......	.7	......	......	......	......	......	......	......	.2
4½ to 5½ feet	......	......	......	......	......	......	......	......	......	......

Taking the combined areas as a whole, more than three times as many seedlings were killed by other causes as were killed by sheep grazing, and five times as many were injured. The injury to leaders and side branches of Douglas fir and lowland white fir was principally due to late frosts, which in 1913 and 1914 killed back much of the new growth on these species. This injury was less serious on the Deadwood than on the other areas, probably because growth commences several weeks later at the higher altitudes. The pines, especially western yellow pine, are attacked by a tip moth whose larva develops in the leader and finally cuts it off. Other injuries were due to rodents (rabbits and porcupines especially), birds (particularly grouse), and fungous diseases of needles and bark.

TABLE 11.—*Deaths and injuries on all plots, due to causes other than sheep grazing.*

Year and species.	Deadwood.						Silver Creek.				
	Needles.	Side branch.	Leader.	Bark.	Tram-pled.	Killed.	Needles.	Side branch.	Leader.	Bark.	Killed.
1912:											
Western yellow pine	1	......	58	4	1	19	......	......	18	1	525
Douglas fir	......	1	20	......	2	57	......	......	3	......	19
Lodgepole pine	......	......	11	2	1	13	......	......	......	......	......
White fir	......	......	......	......	......	......	......	......	......	......	1
All	1	1	89	6	4	89	......	......	21	1	545
1913:											
Western yellow pine	1	2	76	6	......	709	......	......	65	2	1,222
Douglas fir	......	......	61	......	......	273	......	......	20	......	244
Lodgepole pine	......	......	19	1	......	593	......	......	......	......	......
White fir	......	......	......	......	......	......	......	......	2	......	11
All	1	2	156	7	......	1,575	......	......	87	2	1,477
1914:											
Western yellow pine	3	2	55	......	......	518	1	4	23	2	487
Douglas fir	......	26	262	......	......	220	......	46	468	......	269
Lodgepole pine	......	1	15	......	......	620	......	......	......	......	......
White fir	......	......	......	......	......	......	......	21	116	......	19
All	3	29	332	......	......	1,358	1	71	607	2	775
All years total	5	32	577	13	4	3,022	1	71	715	5	2,797

TABLE 11.—*Deaths and injuries on all plots, due to causes other than sheep grazing*—Con.

Year and species.	South Fork.						All areas.					
	Needles.	Side branch.	Leader.	Bark.	Trampled.	Killed.	Needles.	Side branch.	Leader.	Bark.	Trampled.	Killed.
1912:												
Western yellow pine	......	......	......	......	......	......	1	......	76	5	1	544
Douglas fir	......	......	......	......	......	......	......	1	23	......	2	76
Lodgepole pine	......	......	......	......	......	......	......	......	11	2	1	13
White fir	......	......	......	......	......	......	......	......	......	......	......	1
All	......	......	......	......	......	......	1	1	110	7	4	634
1913:												
Western yellow pine	......	......	......	......	......	......	1	2	141	8	......	1,931
Douglas fir	......	......	......	......	......	......	......	......	81	......	......	517
Lodgepole pine	......	......	......	......	......	......	......	......	19	......	......	593
White fir	......	......	......	......	......	......	......	......	2	......	......	11
All	......	......	......	......	......	......	1	2	243	8	......	3,052
1914:												
Western yellow pine	2	1	43	5	2	142	6	7	121	7	2	1,147
Douglas fir	......	19	218	......	......	62	......	91	948	......	......	551
Lodgepole pine	......	......	......	......	......	......	......	1	15	......	......	620
White fir	......	......	......	......	......	......	......	21	116	......	......	19
All	2	20	261	5	2	204	6	120	1,200	7	2	2,337
All years total	2	20	261	5	2	204	8	123	1,553	23	6	6,023

TABLE 12.—*Comparative damage from sheep grazing and from other causes.*

(All allotments and years.)

Species and cause of injury.	Nature of injury.						
	Needles.	Side branch.	Leader.	Bark.	Trampled.	All not killed.	Killed.
Western yellow pine:							
Sheep	51	12	116	8	57	244	1,234
Other	8	9	338	20	3	378	3,622
Douglas fir:							
Sheep	......	5	21	1	25	52	275
Other	......	92	1,052	......	2	1,146	1,144
Lodgepole pine:							
Sheep	3	3	7	......	18	31	256
Other	......	1	45	3	1	50	1,226
White fir:							
Sheep							17
Other	......	21	118	......	......	139	31
All species:							
Sheep	54	20	145	9	99	327	1,782
Other	8	123	1,553	23	6	1,713	6,023

Table 14 shows the causes of death in 1913 and 1914, as far as could be ascertained with a fair degree of certainty. Of the several hundred deaths whose cause could not be determined, most were probably due to drought or a combination of drought and excessive heating of the surface soil. This is the most serious obstacle to successful reproduction in the western yellow pine type. "Winter-killed" in the first column of the table really embraces a number of causes, including drought, frost, fungus, and others.

TABLE 13.—*Comparative damage from sheep grazing and from other causes.*

(All years and species.)

Allotment and cause of injury.	Nature of injury.						
	Needles.	Side branch.	Leader.	Bark.	Trampled.	All not killed.	Killed.
Deadwood:							
Sheep	34	4	65	7	84	194	753
Other	5	32	577	13	4	631	3,022
Silver Creek:							
Sheep	18	7	68	1	11	105	970
Other	1	71	715	5		792	2,797
South Fork:							
Sheep	2	9	12	1	4	28	59
Other	2	20	261	5	2	290	204

TABLE 14.—*Causes of deaths of seedlings between the end of the summer of 1912 and the end of the summer of 1914.*

Cause of death.	Less than 1 year old.			More than 1 year old.		
	Western yellow pine.	Douglas fir.	Lodgepole pine.	Western yellow pine.	Douglas fir.	Lodgepole pine.
Sheep:						
Known	520	72	118	201	91	114
Probable	838	119	118	201	99	116
Drought	917	264	523	615	298	267
Winter-killed	523	215	282	216	161	125
Frost			4		2	1
Erosion					1	
Damped off	166	7	2			
Fungus	2	2		110	18	2
Bitten off by rodents or birds	240	5				
Dug up by rodent			1			
Chipmunk				3		
Mole				2		
Rabbits	7			4		
Deer				3		
Bear	6					
Cattle	2			3		1
Horses	2			1		1
Men	12	2	3	20		
Insects				5		
Porcupine				4		
Shade	3		2	4		
Rolling log						1
Crowded	1					
Total	2,719	614	935	1,191	579	514

VALUATION OF DAMAGE.

Using the table of height growth and the average proportions of seedlings of different sizes killed by all agencies on the grazed plots on all areas, curves were constructed to show the per cent of mortality at different ages. Table 15 was read off from these curves, and from it was computed Table 16, which shows the number of seedlings of any age up to 20 years necessary to insure a stand of 100 trees per acre of any of the three species at an assumed maturity of 150 years. These figures allow for deaths from all ordinary causes, including grazing every year, but, of course, do not allow for extraordinary deaths due to such causes as fires or epidemics of insects or of fungous diseases.

TABLE 15.—*Average mortality from all causes on grazed areas of seedlings of different ages.*

Year of age.	Deadwood.			South Fork.	
	Western yellow pine.	Douglas fir.	Lodge pole pine.	Western yellow pine.	Douglas fir.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	82	80	50	82	80
2	42	47	35	41	47
3	27	28	24	22	28
4	20	20	16	14	18
5	15	16	11	9	13
6	11	12	7	7	10
7	8	10	5	5	8
8	6	8	4	4	6
9	5	6	3	3	4
10	4	5	2.5	2.5	3
11	3	4	2	2.5	2.5
12	2.5	3	1.5	2	2
13	2	2.5	1.5	2	1.5
14	2	2	1.5	2	1
15	2	1.5	1	1.5	1
16	1.5	1.5	1	1.5	.5
17	1.5	1	1	1.5	.5
18	1.5	1	1	1.5	.5
19	1.5	1	1	1	.5
20	1.5	1	1	1	.5
21 to 25	1	.5	.5	1	.5
26 to 30	1	.5	.5	.5	.5
Over 30	.5	.5	.5	.5	.5

TABLE 16.—*Average number of seedlings per acre at different ages necessary to insure a stand of 100 trees per acre of any of the three species at 150 years, if ordinary grazing every year is permitted.*

At beginning of year.	Deadwood.			South Fork.	
	Western yellow pine.	Douglas fir.	Lodgepole pine.	Western yellow pine.	Douglas fir.
1	6,700	6,850	1,475	4,350	5,170
2	1,200	1,370	735	790	1,085
3	700	725	480	470	575
4	510	525	365	365	415
5	410	420	305	315	340
6	345	350	270	290	295
7	310	310	255	270	265
8	285	280	240	255	245
9	265	255	230	245	230
10	255	240	225	240	220
11	245	230	220	230	215
12	235	220	215	225	210
13	230	215	210	220	205
14	225	210	205	215	200
15	220	205	205	210	195
16	215	205	200	205	195
17	210	200	200	200	195
18	210	200	195	200	190
19	205	195	195	195	190
20	205	195	195	195	190
21	200	190	190	190	190

On the basis of the material in United States Department of Agriculture Bulletin 418, "Western Yellow Pine in Oregon," a full stand of western yellow pine of 16 inches diameter, approximately 150 years old, should have about 40 trees per acre. This would mean a volume of about 10,000 board feet. A small, even-aged stand on the Payette Forest, approximately 150 years old, had 230 trees per acre, practically all western yellow pine, between 10 and 22 inches diameter, besides 160 trees below 10 inches; and its volume (trees 10 inches and over) was approximately 23,000 board feet per acre. This is very exceptional for a stand in virgin forest, but may be possible with managed forests.

If 40 trees per acre are assumed to constitute a full stand, but 0.4 as many seedlings as are indicated in Table 16 will be needed; but if 200 trees per acre are assumed, the figures in the table should be doubled. If a full stand of Douglas fir is taken as 167 trees,[1] the figures should be increased by two-thirds for Douglas fir stands. Assuming 250 trees per acre [2] as normal for lodgepole pine at maturity (140 years) the figures in Table 16 should be multiplied by 2.5—that is, there should be approximately 3,700 seedlings the first year.

TABLE 17.—*Amount of reproduction on all plots, spring of 1914, reduced to a per acre basis.*

(All sizes up to 5½ feet high.)

Allotment.	Number per acre.					Per cent of total.			
	Western yellow pine.	Douglas fir.	Lodgepole pine.	White fir.	Total.	Western yellow pine.	Douglas fir.	Lodgepole pine.	White fir.
Deadwood	3,450	2,870	2,750	....	9,070	38	32	30	....
Silver Creek	6,580	3,940	....	910	11,430	58	34	....	8
South Fork	5,050	2,070	....	....	7,120	71	29	....	....

Table 17, which shows the number of seedlings per acre actually present on the plots on all three allotments in the spring of 1914, indicates plainly that there was sufficient reproduction present to make a full stand in spite of grazing injuries. On areas as well stocked with reproduction as those covered by the study the comparatively small amount of scattered injury which results when the stock is carefully managed can hardly be said to represent a tangible loss of value. Where the number of seedlings present is already insufficient to make a full stand at maturity, or where injuries are concentrated, as on trails, bed grounds, or very seriously overgrazed areas, so as practically to eliminate all reproduction over a continuous area of any considerable size, there is a loss.

If seed trees are present in sufficient quantity to reseed the area, the loss will equal the value of the growth already made by the seedlings, which at 10 years of age will be approximately 30 cents per acre or $0.001 per tree if there are less than 300 seedlings per acre, and at 20 years 75 cents per acre or one-third of a cent per seedling where there are less than 250 per acre. These values, which are based on an average annual increment (for a 150-year rotation) of 100 board feet per acre and a stumpage price of $5 per 1,000 feet, are liberal.[1] With an average annual increment of 200 board feet, which may be possible on the best sites, the loss would be 60 cents and $1.50 per acre at 10 and 20 years.

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[1] See Bulletin 418.

[2] See United States Department of Agriculture Bulletin 154, "Life History of Lodgepole Pine in the Rocky Mountains," by D. T. Mason, p. 31.

In case of restocking open burns, clear-cut areas, or plantations, where the reproduction must be replaced artificially, the loss will be the above cost plus the cost of restoration, which has been estimated at $9 per acre for eastern Oregon; $10 per acre, or 4 to 5 cents per tree, will cover the whole loss. Such areas of total destruction need not occur with regulated grazing, except possibly in the case of a few driveways which for topographic or other reasons can not be so located as to avoid injury; and unless the range is overstocked these can in any case be kept very small.

BENEFITS OF SHEEP GRAZING TO THE FOREST.

Benefits to the forest resulting from the use of the range may often offset the slight damage done by regulated grazing. These benefits may consist in direct aid to forest reproduction or in lessening the danger of serious fires.

AID TO REPRODUCTION.

The value of sheep grazing in helping tree reproduction to start is frequently overestimated. It does result in more abundant germination under certain conditions, viz, in case of heavy grazing on poor sites. A pair of plots on a very poor lodgepole pine site, similar in all respects except in the intensity of grazing on them, showed this result:

	Bed ground, 1912.	Lightly grazed, 1912.
Area (square feet)	800	800
Seedlings over 1 year old	None.	None.
Germinated, 1913	75	17

In this case the soil was so dry and lacking in organic matter as to be very unfavorable to reproduction, but the sheep, bedding in the same place for several successive nights, left a thick layer of mulch, so that seedlings not only germinated in greater numbers, but grew much more vigorously than those on the lightly grazed plot. As is usually the case where an area is excessively overgrazed, all of the reproduction already on this bed ground was severely browsed and much of it killed.

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[1] See Bulletin 418.

Table 9 also shows an increase in germination on the most closely grazed areas, but indicates that light or moderate grazing did not have this result; while a series of plots on sites naturally favorable to reproduction showed that on such sites even close grazing may not result in greater germination. These plots showed this result:

	Bed ground, 1912.	Lightly grazed, 1912.
Area (square feet)	1,380	1,380
Seedlings over 1 year old	41	40
Germinated, 1913	128	235

The theory is often advanced that sheep grazing aids the seeds to germinate by "harrowing" them into the soil. This might be an important factor if the grazing were done after the seeds fall; but since the cones usually do not begin to open to any great extent until September, near the end of the grazing season, and since most of the germination takes place before the sheep go on the timbered range in the spring, the benefit is slight. As lodgepole pine seed begins to fall somewhat earlier than the other species and germinates during most of the summer and fall, its germination may be considerably helped by the "harrowing-in" process.

It it probably not true that sheep by loosening the soil and eating competing foliage help seedlings to survive. Table 18, in which the total deaths between the fall count in 1913 and the first count in 1914 are grouped according to the intensity of grazing during 1913, shows that the proportion of survival through the winter was slightly greater on grazed areas than on those which were not grazed. Table 10, however, shows plainly that the sheep did not help seedlings to live through the summer season and Table 9 shows that the greater mortality on grazed areas during the summer more than balanced the slight gain in survival over winter plus the increased germination on grazed areas.

TABLE 18.—*Deaths from all causes between last count, 1913, and first count, 1914, according to intensity of grazing in 1913. Per cent of number on plots, fall 1913.*

(Deadwood and Silver Creek.)

	Western yellow pine.	Douglas fir.	Lodgepole pine.	White fir.	All.
Number of seedlings	5,392	4,083	2,892	237	12,604
Per cent died on:					
All ungrazed plots	12.0	8.5	14.5	3.0	11.4
All grazed plots	10.7	6.6	9.3	2.2	9.0
Per cent in favor of grazed plots	1.3	1.9	5.2	.8	2.4
Died on "moderately" grazed plots	9.7	5.2	12.4	2.6	8.6
Per cent in favor of "moderate" grazing	2.3	3.3	2.1	.4	2.8

PROTECTION AGAINST FIRE.

The most important benefit to the forest which can be attributed to grazing is the reduction in quantity of inflammable ground cover and the consequent decrease in fire hazard. It is not probable that the number of fires can be reduced in this way, but their intensity and consequently their size and the amount of damage done, is bound to decrease with a decrease in the quantity of fuel on the ground. This is particularly apt to be true in a forest of the western yellow pine type, where fire seldom runs in the crowns but nearly always on the ground. If the ground cover is scanty, the older timber is to a certain extent immune from serious damage by surface fires and there is more likelihood that occasional patches of reproduction will escape destruction. Entire denudation of the soil, such as occurs on much-used bed grounds and along driveways, absolutely prevents fires from spreading in such places, but of course destroys any reproduction which may be present. Light or moderate grazing does not remove enough of the cover to stop fires, but may considerably reduce their heat and rapidity of spread and make them easier to combat.

MANAGEMENT OF GRAZING.

The points brought out in the study suggest a number of principles for the management of grazing in western yellow pine and, with slight modifications, in the other timber types of the region. These principles are based on (1) the utilization of the forage in the way most advantageous to the stockman, (2) the welfare of the forest reproduction, (3) the reduction of the fire hazard.

TIME TO GRAZE.

In general, the range should be grazed before the forage becomes dry and unpalatable. Grazing should start in the lower parts of the western yellow pine country (3,000 to 4,000 feet altitude) early in May and practically close by the middle or end of July. The higher altitudes can be grazed from about June 1 to the end of July, or, in wet seasons, to the middle of August. Areas consisting largely of grass or weed range should be used first, since they contribute largely to the inflammable ground cover of August. Besides, if they are fed off early, they will often produce another crop of foliage or seeds before the end of the season. Areas where there is great likelihood of fires starting should be grazed before the dry season begins. Areas upon which most of the reproduction is under 3 years old should be grazed as late in the season as is possible with proper utilization of the feed, since they are the least liable to injury. Such areas should not be grazed when the ground is saturated, especially early in the season.

INTENSITY OF GRAZING.

As a general rule the range should be grazed just enough to remove the greater part of the palatable forage. Extensive browsing of the less palatable species or of conifer reproduction is the best evidence that an area is being grazed too closely not only for the good of the range but also for the best interest of the stock.

Steep slopes with loose soil, particularly where the seedlings are less than a foot and a half high, and reproducing burns, clear-cut areas, or plantations with seedlings up to 5 or 10 years old, depending on the site, should be grazed rather lightly, especially in the first part of the season or during a wet period. In many instances it will be desirable to eliminate grazing entirely from plantations or other areas of seedlings less than three years old. During a dry season spots where danger of fire is greatest may be grazed as closely as possible. Very close grazing is also permissible on areas poorly stocked with reproduction where a heavy crop of seed is expected in the fall, or where artificial reseeding is planned. If a good catch of seedlings takes place such areas should be grazed very lightly or not at all for at least three years succeeding the seed year.

The carrying capacity of western yellow pine range varies so widely with the locality and the season that no definite figures can be laid down which will have a general application. Much of the poorer range, such as that on the Deadwood allotment, will require up to 10 acres per grown sheep for a 60-day season; while the best range will sometimes, with favorable weather conditions, average two acres per sheep over limited areas. An average for most of the better class western yellow pine areas is approximately from three to four acres per sheep.

METHODS OF HANDLING.

HERDING.

The sheep should be allowed to scatter out and graze with as little disturbance as possible. No attempt should be made to keep them in a compact bunch, except for convenience and safety when they bed down at night, and at such times they should be gathered together with a minimum of driving or excitement. The use of dogs should be avoided as far as possible.

Driving the sheep to and from water, bed grounds, or different parts of the allotment is seldom necessary and should be avoided. When it is necessary to drive them, they should be taken where damage from trampling is least apt to occur, such as areas with no reproduction or with plenty of seedlings over 1.5 feet high, or places where complete removal of foliage and denudation of the soil is desirable to reduce the fire hazard.

DRIVEWAYS.

The driving of the sheep in fairly compact bands to and from their allotments in spring and fall can hardly be avoided, but in many cases great damage to the forest can be prevented by careful location of driveways in places least subject to damage. Areas without small reproduction, untimbered areas where danger of erosion is not serious, sites which are too poor to produce merchantable timber in a reasonable rotation, such as dry, rocky ridges with little soil, are examples of such places. Although usually impracticable from the administrative standpoint, it may sometimes be possible to reduce considerably the amount of injury by changing the location of such driveways from year to year, by limiting the number of bands of sheep which may use the same one, by limiting the time each band may spend on the trail, and by making the trail wide enough to supply feed for all the stock which use it.

It will very often be possible to locate the driveways so that they will be an advantage to the forest. Such areas make excellent fire breaks for stopping light surface fires and for use in back-firing and fighting severer fires. When it is possible, they should be located near places of great fire danger. For instance, closely grazed strips along roads, trails, railroads, or around camping places, sawmills, and the like, will be of considerable value in preventing the spread of incipient fires from such places. In such cases due regard should of course be had for the rights of other users; for instance, sheep should not be allowed to graze on camp grounds or so close to them as to make conditions unpleasant for campers, nor should feed necessary for pack and saddle animals be eaten off near camping places, nor should areas much frequented by travelers and tourists be grazed in such a way as to impair their scenic beauty. Similar trails along the edges of burns, reproduction areas, or slashings will be of much value in fire control. Such strips should, of course, be fed clean every year, and the more closely they are grazed the better.

SALTING.

Sheep should be supplied with all the salt they want, at least every five or six days, so that they will not trail around hunting for it. They should be salted in a different place each time, and the salt should be so well distributed that they will not bunch up closely and cause serious injury to the forage cover and forest reproduction by trampling. Bed grounds are good places to supply the salt; for if the stock spend part of their time there eating salt, they will have less time to graze or browse conifers.

WATERING.

In the particular locality studied water is so well distributed that driving to water was not necessary. In places less plentifully supplied much of such driving can be eliminated by the development of watering places. It is also important to remember that sheep do not ordinarily require water every day, but, especially during rainy periods, can do without it for several days.

BEDDING.

The most serious damage to reproduction under the old unrestricted methods of herding was due to repeated use of the same camp and bed ground, which not only resulted in the entire denudation of the area so used, but necessitated much driving back and forth at morning and night. This damage can be very largely eliminated by the so-called "bedding-out" method of herding in which the herder moves around with the sheep and camps near wherever they stop at night. As they bed in a different place each night no driving is necessary.

By locating bed grounds where liability to damage is least—either because of lack of small reproduction, presence of plenty of palatable forage not previously eaten off, or of sod cover—the injury which is inevitable in such places can be reduced to a negligible amount. It is also advisable in places which are liable to considerable damage, such as areas with only a limited stock of seedlings, areas of reproduction mostly less than 1.5 feet high, and areas with loose and easily disturbed soil, not to use the same bed ground in two successive years.

If the sheep are not gathered on the bedding area until nearly dark and are herded off soon after daylight, the injury from browsing will be much less than if they are allowed to feed on the one spot for several hours.

On bare dry ridges where natural soil conditions have not allowed reproduction to become established, severe and repeated use of bed grounds may often be desirable to fertilize the soil so that seedlings can grow on it. As with driveways, bed grounds may often be so located and used as to be of considerable assistance in reducing fire hazard. In places where danger is great repeated use of the same area will be desirable.

None of the foregoing suggestions is impracticable or contrary to the best interests of the stock owner. To carry them out will require in many cases a somewhat higher grade of camp tenders and herders and better supervision, consequently the cost of the business may be slightly greater than with the old unrestricted and usually rather careless methods of herding. This additional cost will be much more than repaid by the increased returns from meat and wool, for it is a well-known fact that sheep do best when they are disturbed as little as possible and bunched or driven around no more than is absolutely necessary. It is obvious that they will keep in better condition if held on palatable feed than if kept on an area after the feed is gone so that they have to eat unpalatable species such as conifers. With careful application of these principles injury to forest interests will be reduced to practically nothing, the forest will in many cases benefit largely by reduction of the fire hazard, and, whether or not there is an actual increase in the number of head grazed on a given area, there will be considerable increase in the quantity and improvement in the quality of the meat and wool produced.

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